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[54] **METHOD OF AND APPARATUS FOR EVALUATION AND MITIGATION OF MICROSLEEP EVENTS**

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[56] **References Cited****U.S. PATENT DOCUMENTS**

4,006,539	2/1977	Slomski	434/258
5,012,226	4/1991	Love	340/576
5,243,339	9/1993	Graham et al.	.....	340/945
5,304,212	4/1994	Czeisler et al.	.....	607/88
5,325,862	7/1994	Lewis et al.	.....	600/544
5,339,818	8/1994	Baker et al.	.....	600/490
5,433,223	7/1995	Moore-Ede et al.	.....	128/898
5,447,166	9/1995	Gevins	.....	600/544
5,568,126	10/1996	Anderson et al.	.....	340/574
5,583,590	12/1996	Clupper	.....	351/200
5,590,665	1/1997	Kanai	.....	128/898
5,595,488	1/1997	Gozlan et al.	.....	434/236
5,601,090	2/1997	Musha	.....	600/544
5,610,673	3/1997	Rafal et al.	.....	351/210
5,620,436	4/1997	Lang et al.	.....	606/4
5,645,550	7/1997	Hohla	.....	606/108
5,689,241	11/1997	Clarke, Sr. et al.	.....	340/575
5,691,693	11/1997	Kithil	.....	340/575
5,699,449	12/1997	Javidi	.....	382/156

OTHER PUBLICATIONS

A. J. Gabor, R.R. Leach, F. U. Dowla, Automated seizure detection using a self-organizing neural network; *Electroencephalography and clinical Neurophysiology* 99 (1996), pp. 257–266.

M. Groezinger, J. Roeschke, B. Kloepfel; Automatic recognition of rapid eye movement (REM) sleep by artificial neural networks; *J. Sleep Res.* 4 (1995), pp. 86–91.

G. Jando, R. M. Siegel, Z. Hovath, G. Buzsaki; Pattern recognition of the electroencephalogram by artificial neural networks; *Electroencephalography and clinical Neurophysiology* 86 (1993), pp. 100–109.

T.-P. Jung, S. Makeig, M. Stensmo, T. J. Sejnowski; Estimating Alertness From the EEG Power Spectrum; *IEEE Transactions on Biomedical Engineering* 44 (1997), pp. 60–69.

(List continued on next page.)

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[57] **ABSTRACT**

A method and apparatus for determining, monitoring and predicting levels of alertness by detecting microsleep episodes includes a plurality of channel processing units and a channel combining unit. Each of the channel processing units receives an information channel which conveys information associated with the mental and behavioral state of the subject, such as for example an EEG channel, and classifies the information into a distinct category. Such categories may include microsleep, non-microsleep, one or more of a plurality of stages of sleep, one or more of a plurality of stages of wakefulness, or a transition state characterized by a transition from one of the aforementioned states to another. Each of the channel processing units includes a neural network which has been trained with a set of example input/result vector pairs. The example input/result vector pairs are generated by correlating actual information channel outputs with observed fatigue related events such as nodding off, head snapping, multiple blinks, blank stares, wide eyes, yawning, partial and complete prolonged eyelid closures, and slow rolling eye movements.

42 Claims, 16 Drawing Sheets